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SPACE CONSTANCY ON VIDEO DISPLAY TERMINALS

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Interim Report for Period 1 January 1991 - 31 December 1991

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Summary

Work for the grant's second year progressed in four projects. The first, a report of distorted space processing in flickering fields, concerns empirical work completed before the current review period. The paper resulting from this work was revised and published in a leading journal during the review period. The second project extended this work to high-speed flicker, at 480 and 960 Hz. No evidence was found that these high flicker rates have any advantages over slower rates, though some technical issues were resolved. The third project examined reading rates on CRT screens at 60 and 500 Hz. The faster rate resulted in reading that was on average 0.6 msec faster, a difference that is neither statistically reliable nor of practical consequence. Technical problems in that study were addressed in the fourth study, using more subjects and a larger and more difficult sample of reading material, with eye movement monitoring and an automatized screen refresh procedure. Initial results showed a small advantage in reading speed at the higher frequency for 4 of 6 subjects, and an overall advantage of 5 words/min at 500 Hz. Data collection is continuing in this project.

1.) Flicker Distorts Visual Space Constancy

In this project a small target was flickered at 33, 66, 130 or 260 Hz, and the threshold for detecting its displacement was measured during saccadic eye movements. Details of the apparatus used are similar to those in study #2 below. Sensitivity to displacement was about twice as great when the target was moved in the direction opposite the eye movement as when it was moved in the same direction. This would be expected from a partial breakdown of space constancy -- the world should seem to jump in the direction opposite to an eye movement. Even if a suppression of displacement detection during saccades prevents the jump from being perceived, it should be easier to detect a target displacement in the direction opposite the eye movement than in the same direction: when movement is opposite, the imposed displacement adds to the illusory displacement, making detection easier. Displacements were more easily detected at lower flicker rates. The results imply that both masking and extraretinal signals are important in suppressing the detectability of target displacements during saccades, and that flicker on video display terminals may distort space perception.

The empirical work on this study was completed before the start of the year currently being reviewed. Work on this project during the review period was limited to revisions in the manuscript in response to *Vision Research* reviewers. The revisions included a complete reworking of figures clarifying the retinal smear conditions at various flicker rates, compared with the smear that occurs under the same stimulus conditions but superimposed on a simultaneous saccadic eye movement. Revisions were also made to the review and discussion, and the paper appeared in December 1991 (see appendix).

2.) Space Constancy in High-speed Flicker

Like study #1, the question being asked in this study is how flicker changes

space constancy. By flickering the target object the temporal component of space constancy is manipulated, and by displacing the target in the visual field the spatial component can also be probed. The amount of flicker can be varied while oculomotor demands and the appearance of the image during fixation remain the same.

A flickering target remains spatially constant as long as the eye is fixating the target, so that location is defined. During a saccade the information available about stimulus location will lag behind eye position (Macknik, 1991). Because information from a flickering stimulus is not present during the off period of the duty cycle, visual perception must utilize information from the most recent flash. If the eye is moving, this sample will lag behind the actual eye position. Also, a flickering stimulus does not leave a continuous smear on the retina, but rather a series of spatially discrete samples.

The study was designed to further explore the effects that flicker has on the ability to detect movement during a saccade. By including flicker rates of 480 and 960 Hz, faster than those used in study #1 above, we will determine whether the temporal pattern of sampling, or merely the fact that the image is discontinuous, is important in maintaining space constancy.

Methods

Apparatus:

Subjects were dark adapted for 10-15 min with the left eye occluded. With head restrained by a bite bar, the subject sat with the right eye at the center of a HP 1351 vector screen onto which targets were displayed. This device can present stimuli 980 times per sec and has a medium-short persistence p31 phosphor that decays exponentially to 1% brightness in .02 to 2 msec. Since we ran our display at a brightness of 2 log units over threshold, the stimulus always decayed to invisibility in 2 msec or less. This brightness level also prevents any long-persistence phosphorescence of the screen from affecting perception.

The screen was 58.5 cm from the subject's eye. It was 44 deg wide and 32 deg

in height, and was of uniform brightness. Ambient light level at the observer's eye was 0.12 cd/m2 . The display was controlled by a computer via a HP display buffer. Duty cycle was held constant at 50% for all stimuli.

Horizontal saccadic eye movements were recorded with a photoelectric infra-red eye tracking system and sampled by the computer. An infrared LED illuminated the viewing eye, and paired photocells were aimed at the iris-sclera border.

Design and Procedure:

The subject fixated the leftmost target (fig. 1A) and signalled readiness by pushing a button. Both the left and right targets then disappeared, leaving only the middle target on the screen (fig. 1B). Subjects had been instructed to saccade at this time to the position where the right target had been (fig. 1C). When the eye passed through the first 7 deg the computer triggered the central target to move in either direction. Targets were 1 degree outline squares. Saccades were on average 40 msec in duration.

Upon reaching the right target spot, if the saccade was of proper length and duration, the screen blanked and was replaced with a question asking whether the target had moved or not. If the saccade was inaccurate, the subject was informed with visual text whether the error was caused by an undershoot, overshoot, or double saccade. Subjects responded by pressing either yes or no on a response box. Since the fixation points had been extinguished, the target jumped in an unstructured visual field. The response was made without either right or left fixation points on the screen. Therefore, no intentional reference frame was provided for the subject.

A MOdified Binary Search (MOBS) system was used to control the trial sequence. The standard binary search method utilizes information gained with each stimulus presentation to determine the next step in the search. The search begins by sampling the midpoint of the range of possible values. Depending on the outcome, a boundary is established that eliminates half the range. The midpoint of the remaining range is sampled next.

Regular binary search fails when the target drifts outside the defined boundaries. MOBS (Tyrrell and Owens 1988) uses a sampling range defined by two boundaries made up of two stacks. The goal of MOBS is to minimize the number of trials before establishment of threshold. MOBS achieves this by presenting each trial at the assumed threshold. Each stimulus presentation is presented at the value midway between the two stacks. After each presentation one of the boundaries is updated. This information is saved and used if the response drifts beyond the boundary. When two consecutive responses are the same, an alternative test is implemented to confirm the validity of the opposite boundary. This tests whether the target is within the active range. If the target drifts beyond a boundary, the invalid boundary is reset to its previous value. This continues until two termination criteria are met. Criterion 1: A certain number of reversals occur. Reversals are consecutive opposite responses. Criterion 2: The last step is less than 5% of the total range. This controls for large drifts in the last response. If these criteria are not met, then the threshold detection procedure continues. The variance within the range has a lawful relationship with the number of reversals. Upon satisfaction of these two criteria, the midpoint is selected as the subject's threshold.

Displacement of the target was determined by MOBS and started between 0 and +/- 3 degrees.

Stimuli:

The middle target in figure 1 was flickered at one of 6 frequencies, 30, 60, 120, 480, or 960 Hz, and had a 50% duty cycle. Before testing the subject held a 99% filter in front of the right eye. Each stimulus was presented to the subject, who to alerted the experimenter when he saw the target. At this point the brightness threshold was set and the filter removed. Each flicker frequency was then presented and adjusted for equal brightness. During the practice phase of the test each subject was instructed to tell the experimenter if any afterimage had appeared on the screen. If a report was given, the session was stopped and brightness calibration was continued.

Analysis:

Analysis of variance (ANOVA) was carried out using a standard statistical package (CRUNCH ANOVA). Two factors, flicker frequency and direction of displacement, were analyzed.

Results

The main effect of flicker frequency on the threshold boundary was established by MOBS. There was no overall main effect of flicker frequency (df= 5,15 F= 1.14 p=.377). A negative bias was found in all but one (120 Hz) of the flicker rates. This result suggests that the flicker biases detection of movement in the direction opposite the saccade by forcing the original zero position (where the target actually started on the screen) in the direction opposite the saccade.

Figure 2 illustrates the flicker -x- direction of movement interaction. This figure shows the range between the thresholds measured in both directions in which no movement was detected. No significant interaction was uncovered (df= 5,15 F= saccadic suppression was effective was the same no matter what the flicker frequency or direction of displacement. Despite these tests, the midpoint of the range was less biased at 30 Hz than other frequencies (Figure 3). The range nonlinearity masked the significance of this result from the linear ANOVA fit. Asymmetry of suppression at the low end of the range is condensed by some 70%.

Thus far all analyses have been performed on thresholds measured relative to the initial position of the stimulus. If the position of the fovea is taken to be the reference from which measurements are to be taken instead of the position of the stimulus, then statements about the distance and time required for the stimulus at the fovea to reach threshold can be made. To do this, all threshold measurements were referenced to the position of the fovea at the moment it passed the trigger (3 degrees before arriving at the stimulus) and an ANOVA was performed on this measured distance. Results of this analysis show that the fovea was significantly closer to the stimulus for displacements in

the direction opposite the saccades (df= 1,4 F= 130 p=.0003).

This difference may result from the sparser spatial sampling on the retina for the stimulus moving in the direction opposite the saccade. There was a smaller probability of the target flickering in the fovea while moving in this direction. The displacement took place when the fovea was closer to the target in the opposite-direction trials than in the same-direction trials. All of these sampling properties reflect what happens on computer terminals that flicker during normal use.

Thresholds from both the stimulus-bound and fovea-based reference frames showed that these two points of reference were significantly different (df= 1,4 F= 22.76 p=.008). The threshold value for each direction of displacement relative to the starting point of the stimulus was combined with the eye movement needed to detect such displacement, measured relative to the trigger, and formed into a ratio value. Movements in the direction opposite the saccade had significantly different threshold/ eye movement ratios than did those in the same direction as the saccade (df= 1,4 F= 11.7 p= .026). This result is further evidence that those movements in the direction of the saccade had more time to start/finish their duty cycles while the fovea was near the target location.

Discussion

Our results suggest that flickering the target object at higher frequencies has no significant effect on the ability to detect movement in the visual field, as long as the flicker exceeds about 60 Hz. However, direction of movement of the stimulus is a discriminating factor in this study. It has been shown (Bridgeman & Fisher 1990) that displacement suppression is symmetrically distributed around the center of the target. All flickers shifted the detection area from a symmetrical distribution to an asymmetrical one. The distance between the two threshold values remained quite constant over all flickers except for 30 Hz.

In flicker studies #1 and #2 the results suggest that no matter what the direction of the saccade, thresholds are biased such that target movements to the right are easier to

detect than movements to the left. This may be related to the more frequent saccades to the right during reading, a subject of current experiments.

When both groups of data were subjected to the same analyses using a stimulus bound reference frame, a foveal based reference frame, and a ratio measure, no statistically significant differences existed between the two groups other than the vantage point offered by the different saccade directions. The original study's threshold values were on average 40% greater than those reported in this study. This suggests that with MOBS a more sensitive measure of threshold was made in the present study. Both the frame-based and foveal-based data suggest that similar suppression was exhibited in both studies.

Those flickers greater than 120 Hz left similar smears on the retina and are suggested to have been processed in the same way. The probability that these stimuli achieved both an on and off phase of their duty cycle while passing through the fovea was high, so that the subject always had both spatial and temporal information at the fovea. If this were the case then a simple match/mismatch distance equation could have been computed to answer the question of whether the stimulus moved.

In this study the direction of a saccade was confounded with the likely retinal location of the target at the time of displacement. This is because the target displacement was triggered when the eye was still 3 deg away from the target, on its way to the center of the field. The displacement was triggered early because saccadic suppression is strongest early in the saccade. A useful comparison condition will be to repeat the experiment with the displacement triggered as the fovea reaches the target location. We would expect less saccadic suppression, but in this case the target would always jump out of the fovea. Recent evidence (Mateeff et al., 1991) that target jumps into the fovea are easier to detect than jumps out of it also have bearing on our results, and this factor can be controlled with targets that jump when the fovea crosses them, so that they always move out of the fovea.

3.) Interaction of Reading Speed and Flicker Rate

Another consequence of flicker on computer terminals may affect not space constancy but reading speed. As a reader makes successive saccades on a flickering screen, the eye may land on a new word at a time when the display has not been refreshed. Does the eye 'park' at this location until a refresh occurs? And would this slow down total reading speed? The predicted effect of these timing differences is small, about 5% of reading speed, but may be of practical significance because of the large amounts of time spent reading from computer terminals. The current study was designed to answer these questions.

Methods

Apparatus:

Reading experiments used the apparatus described in #2 above. Text files stored in the IBM PC were fed to the HP graphics buffer and display system. Characters were displayed at 60 or 500 Hz. All other display characteristics, including brightness, type font, and character size were equal at the two flicker frequencies. The subject saw a few lines of text on the screen, and pressed a button to move to the next sample of text.

Procedure:

Subjects read a series of graded and standardized passages from "Individual Evaluation Procedures in Reading" by T. A. Rakes, J. S. Choate, and G. L. Waller (Englewood Cliffs, N. J.: Prentice-Hall, 1983). Each passage was about 200 words long. Reading rate was measured for 12 passages in each subject; data from the first 2 were discarded as practice passages. The passages were graded to be at the 10th grade level, well below the reading level of our college subject sample. Subjects were instructed to read as fast as possible consistent with comprehension, and they answered a few simple questions about each passage before moving to the next, to assure that the material had

been read.

Results

Reading speeds varied greatly both between subjects and between passages. Speed was faster with the higher flicker frequency, but the difference was small, 0.6 msec, and was not statistically reliable. Because of some procedural problems with this experiment, a second reading study was undertaken and is now nearing completion.

4.) Reading Speed and Flicker II

Several artifacts may have obscured any effects in the study reported above. First, the material was so easy for our college student sample that some readers merely skimmed it. Second, the procedure of pressing a button to obtain the next sample of text was unfamiliar, and slowed the reading of some subjects because some new lines required a button press while others required only a return saccade. Third, the sample of text was too short to obtain a reliable reading speed estimate at each flicker rate. To correct these deficiencies, a second study was run.

Method

The same hardware was used, but the samples of text and procedure differed from study #3. Text was the first chapter of a college textbook in physiological psychology. Standard difficulty measures place the reading level at about grade 14. The text was displayed one full-length line at a time, and each new line was called by a button press. With this method every return involves the same procedure, and the task can become automatized so that it requires minimal time and effort. The chapter consisted of about 7,000 words. Flicker rates were varied without the subjects' knowledge in an ABAB paradigm, following a practice session to familiarize them with the procedure.

Results

Of the six subjects run to date, four showed faster reading in the 500 Hz condition. Table 1 shows within-subject analyses for the frequency comparisons, with reading speed for each line as the dependent variable. In the three subjects in which rates were significantly different ($p<.01$) at the two frequencies, two were in the direction of faster reading at 500 Hz. Individual subject data are summarized in Figure 4. Because individual differences are significant in an overall analysis of variance, about 20 subjects will be run before another analysis is made, and a power analysis will be included.

Overall, the reading rate for all subjects with 60 Hz flicker was 241 words/min, and with 500 Hz flicker was 246 words/min. While this difference is small, it will have practical significance in the real world if it holds up with a larger population. When compared to the 100 million hours/day spent reading on terminals, a difference of this magnitude would correspond to a difference of about 2 million hours/day wasted by terminal flicker.

We are currently running subjects at a rate of about 1/day, including simultaneous preliminary analysis, and we should know whether these effects are reliable in a few weeks. With a larger number of subjects and the large amount of data collected from each, a MANOVA should be the most powerful test of the effects.

Another possible comparison, using the software and procedures already developed, is between non-flickering flat screens and flickering CRT screens, both with brightness and contrast equilibrated and with these values set to the user-preferred values for each format. These studies will be made during the third grant year.

References

Bridgeman, B., Fisher, B., 1990 "Saccadic suppression of displacement is strongest in central vision" Perception, 19, 103 - 111.

Bridgeman, B., Stark, L., 1991 "Ocular proprioception and efference copy in registering visual direction" Vision Research, 31, 1903-1991.

Macknik, S., Fisher, B., Bridgeman, B., 1991 "Flicker distorts visual space constancy" Vision Research, 31, 2057-2064.

Mateeff, S., Yakimoff, N., Hohnsbein, J., Ehrenstein, W. H., Bohdanecky, Z., Radil, T. 1991 "Selective directional sensitivity in visual motion perception." Vision Research, 31, 131-138.

Tyrrell, R., Owens, A., 1988 "A rapid technique to assess the resting states of the eyes and other threshold phenomena: The modified binary search (MOBS)" Behavior Research Methods, and Computers, 20(2) 137 - 141

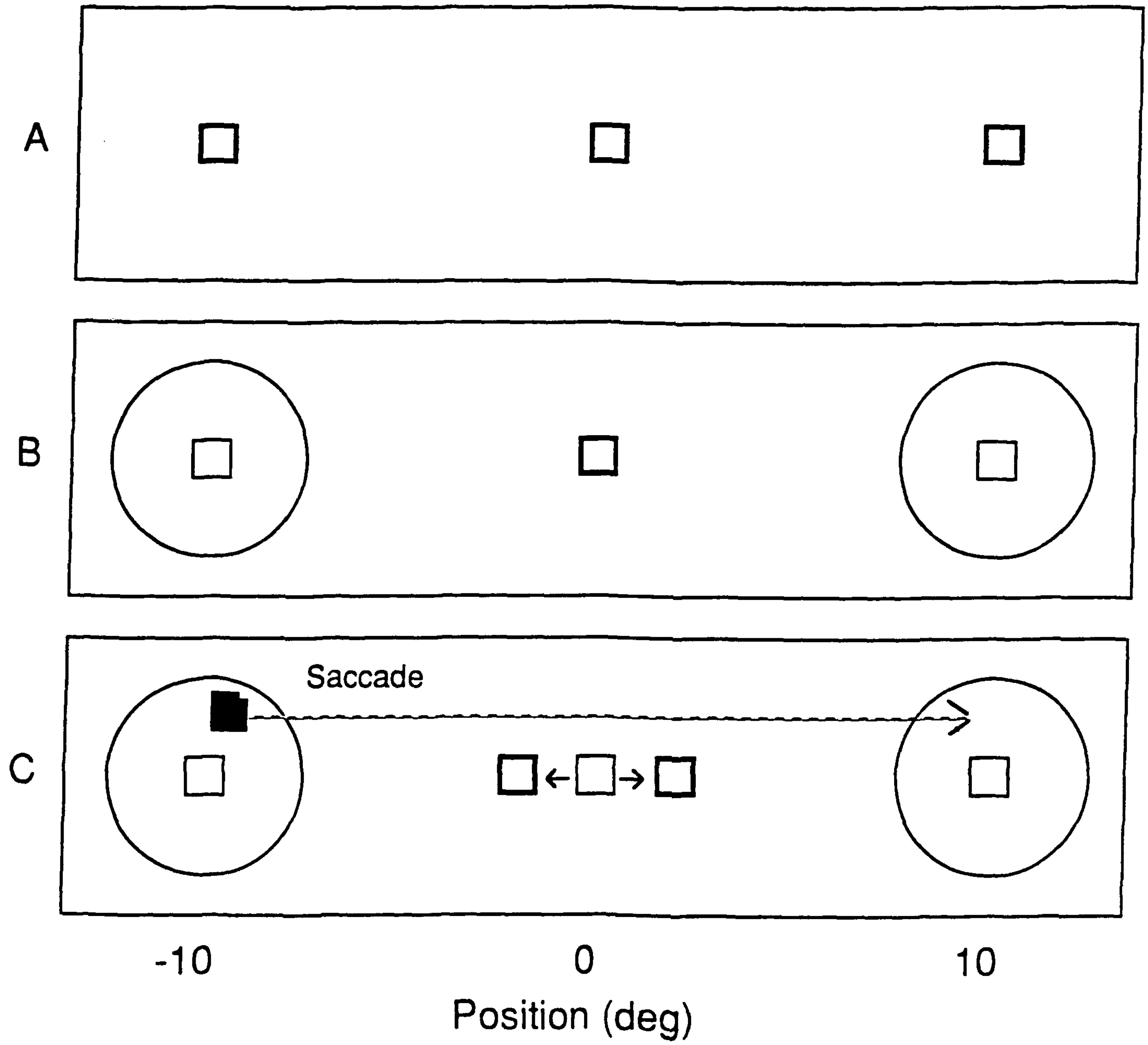


Figure 1.

threshold for movement detection

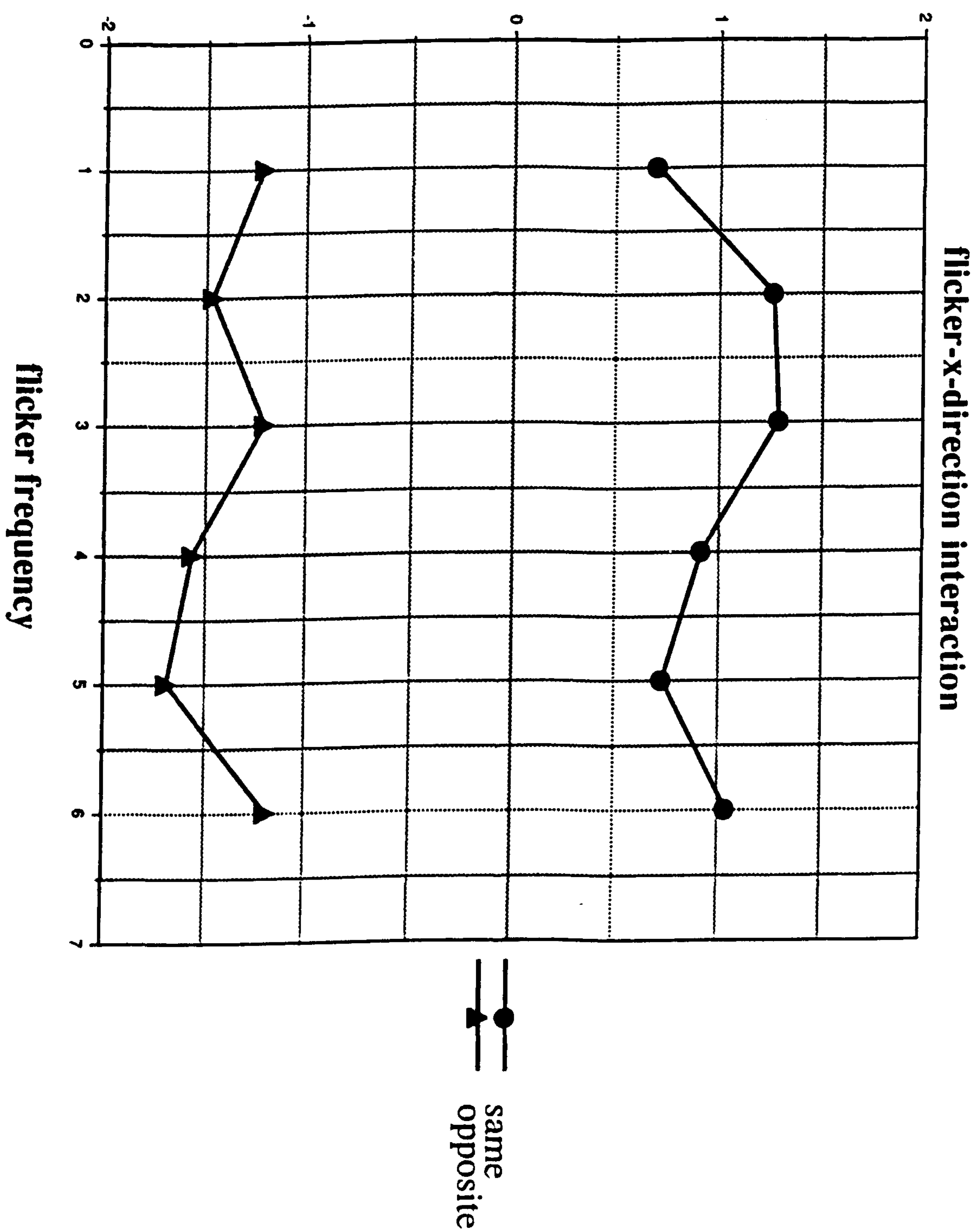


Figure 2.

total range in space and time of
saccadic suppression as measured
distance between left and right
threshold boundries

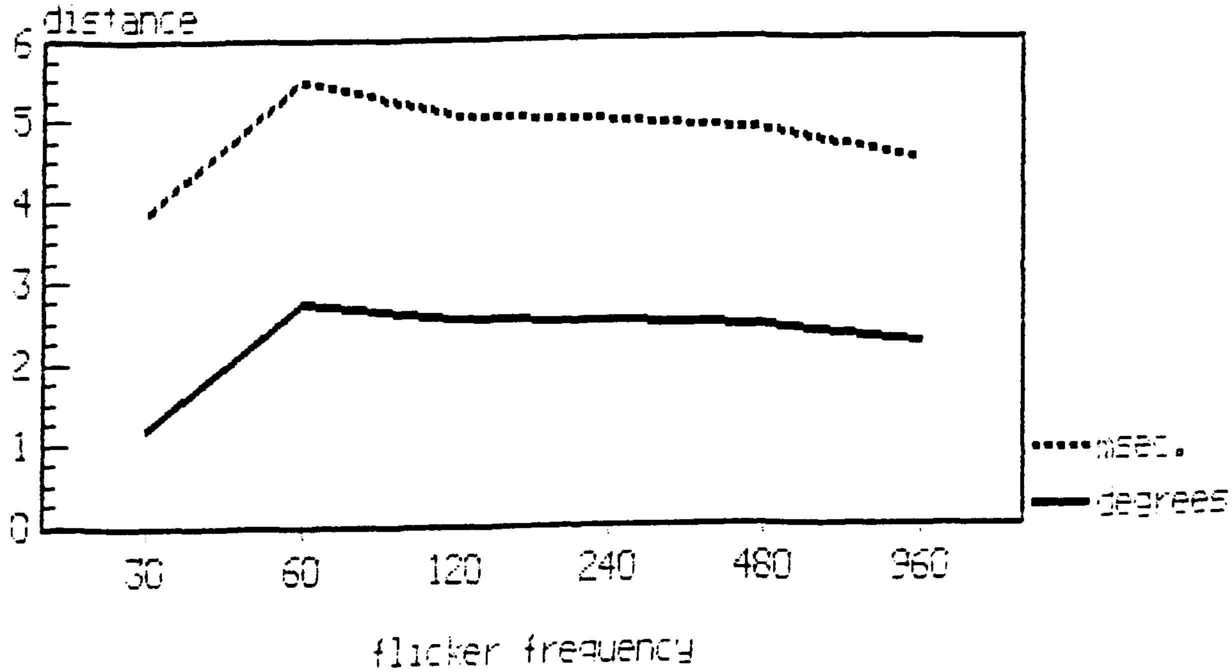
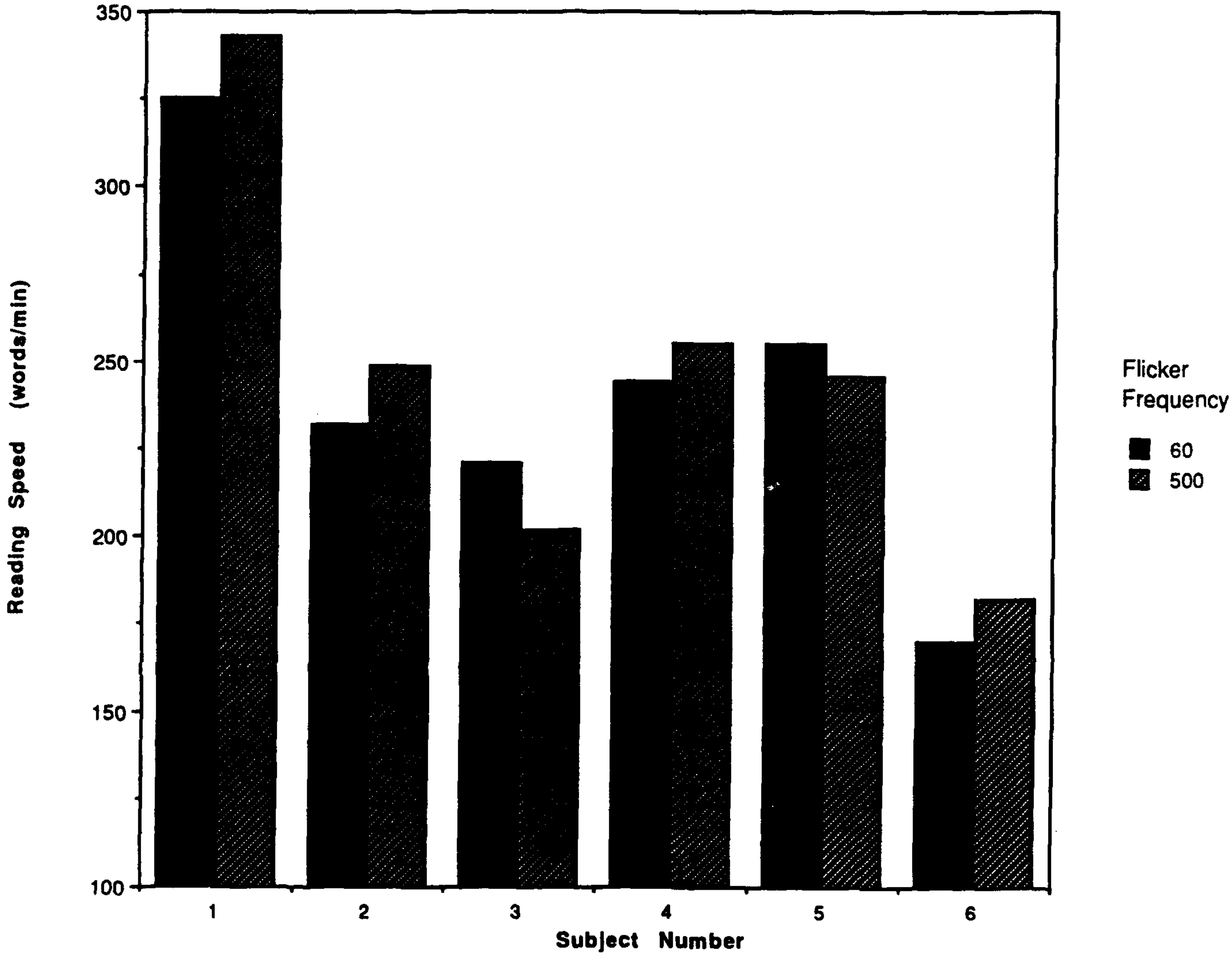


Figure 3.



350
300
250
200
150
100
Reading Speed (words/min)
1
2
3
4
5
6
Subject Number
Flicker Frequency
60
500

Figure 4.

Unpaired t-Test X 1 : Frequency Y 1 : EVB

DF:	Unpaired t Value:	Prob. (2-tail):
505	-1.806	.0715

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	324.813	97.215	6.112
fivehundred	254	342.696	124.02	7.782

Unpaired t-Test X 1 : Frequency Y 2 : JEL

DF:	Unpaired t Value:	Prob. (2-tail):
504	-3.122	.0019

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	231.989	55.173	3.469
fivehundred	253	248.969	66.625	4.189

Unpaired t-Test X 1 : Frequency Y 3 : TGC

DF:	Unpaired t Value:	Prob. (2-tail):
505	3.911	.0001

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	220.906	58.182	3.658
fivehundred	254	201.916	50.932	3.196

Unpaired t-Test X 1 : Frequency Y 4 : TAD

DF:	Unpaired t Value:	Prob. (2-tail):
504	-1.704	.089

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	244.082	64.05	4.027
fivehundred	253	255.141	80.956	5.09

Table 1 (continued on next page).

Unpaired t-Test X 1 : Frequency Y 5 : HIH

DF:	Unpaired t Value:	Prob. (2-tail):
505	1.789	.0742

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	254.687	63.629	4
fivehundred	254	245.549	50.683	3.18

Unpaired t-Test X 1 : Frequency Y 6 : RDN

DF:	Unpaired t Value:	Prob. (2-tail):
504	-4.085	.0001

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	170.428	29.347	1.845
fivehundred	253	181.538	31.782	1.998

Table 1 (conclusion)

Unpaired t-Test X 1 : Frequency Y 5 : HIH

DF:	Unpaired t Value:	Prob. (2-tail):
505	1.789	.0742

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	254.687	63.629	4
fivehundred	254	245.549	50.683	3.18

Unpaired t-Test X 1 : Frequency Y 6 : RDN

DF:	Unpaired t Value:	Prob. (2-tail):
504	-4.085	.0001

Group:	Count:	Mean:	Std. Dev.:	Std. Error:
sixty	253	170.428	29.347	1.845
fivehundred	253	181.538	31.782	1.998

Table 1 (conclusion)